

SEFSC-AOML Biogeochemical Modeling Update

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Introduction and Objectives

- Downscale CMIP5 climate models using a regional ocean-biogeochemical model and study the impact of natural and anthropogenic climate variability on the GoM and apply results to the BFT habitat model.
- MOM4-TOPAZ is used to simulate natural variability of biogeochemical processes in global ocean during 1948-2009. This is a necessary step to better understand and compare the anthropogenic influences and natural variability.
- Global MOM4-TOPAZ simulation is also needed to provide the initial and boundary conditions for the downscaled model.

Modeling biogeochemical processes

Given that the upper ocean circulation largely determines primary production in the euphotic layers, the upper ocean circulation anomalies associated with the AMO may also affect biogeochemical processes in the North Atlantic Ocean.

MOM4-TOPAZ (ocean-sea ice -biogeochemistry model)

Tracers for Ocean Phytoplankton with Allometric Zooplankton (TOPAZ)

- ➔ Includes three phytoplankton groups (i.e., small, large and diazotrophic)
- ➔ Consider 30 tracers (C, N, P, Si, Fe, DO, alkalinity)
- ➔ Diazotrophic phytoplankton: fix atmospheric N_2 directly
- ➔ Includes the oceanic iron cycle including biological uptake and remineralization, particle sinking and scavenging and adsorption/desorption

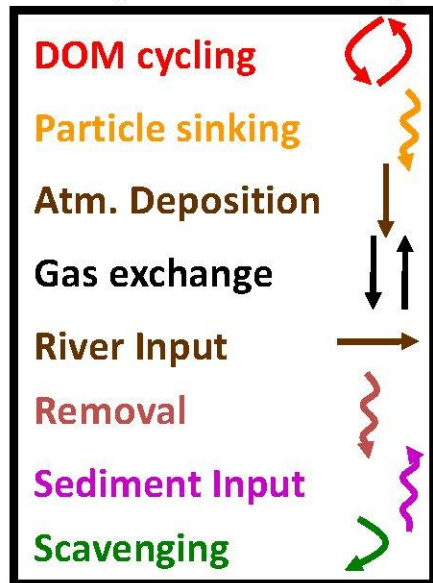
Tracers for Ocean Phytoplankton with Allometric Zooplankton (TOPAZ)

Diatoms and Other Large Phytoplankton
Flexible N:P:Si:Fe:Chl
Aragonite and Calcite

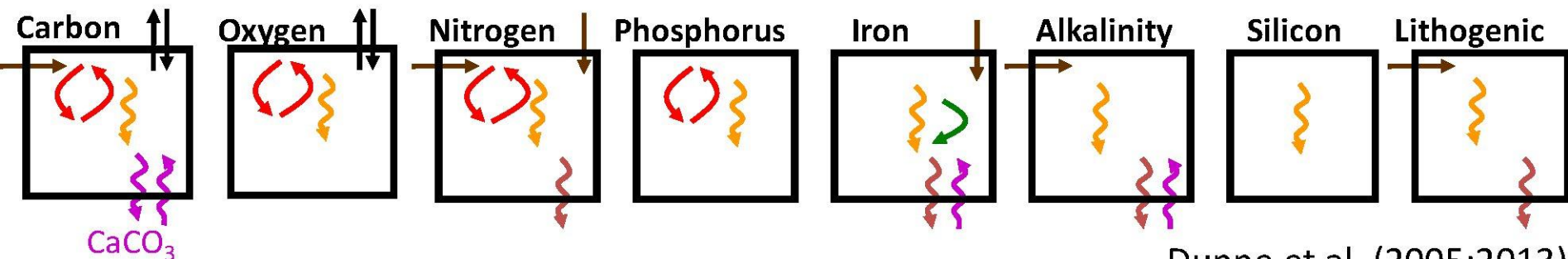
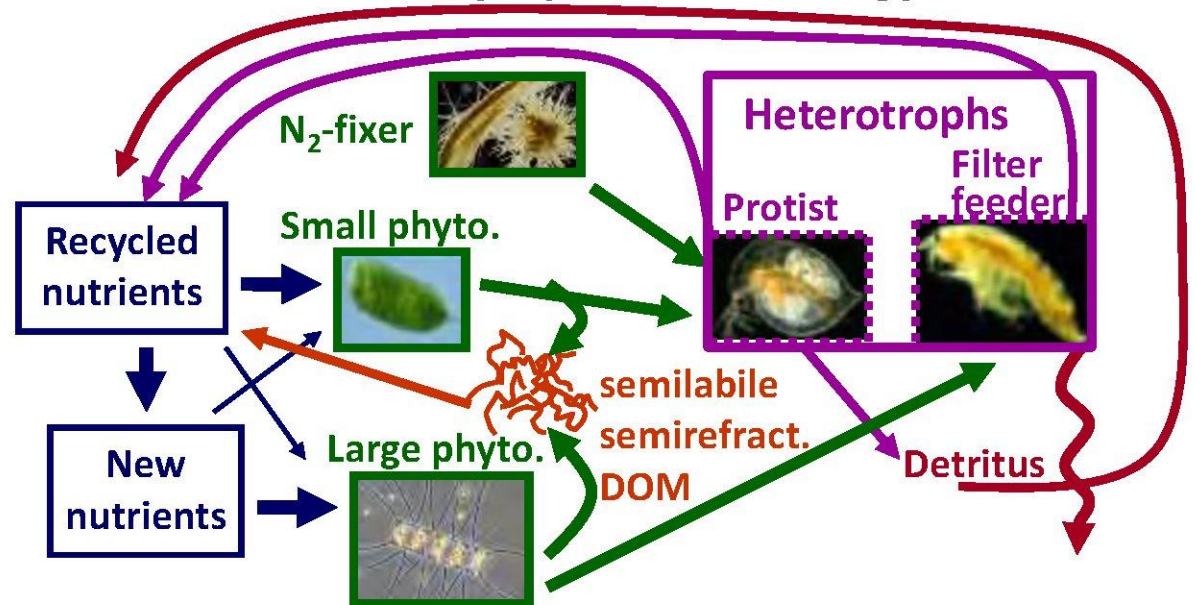
30 Tracers



Biogeochemistry



Phytoplankton ecology



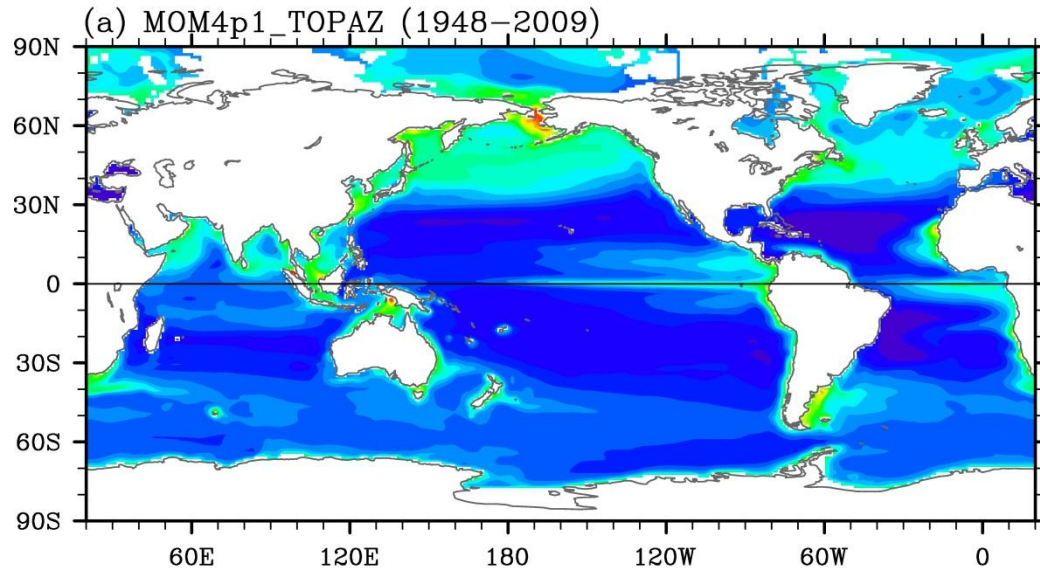
Dunne et al. (2005;2013)

MOM4-TOPAZ Configuration

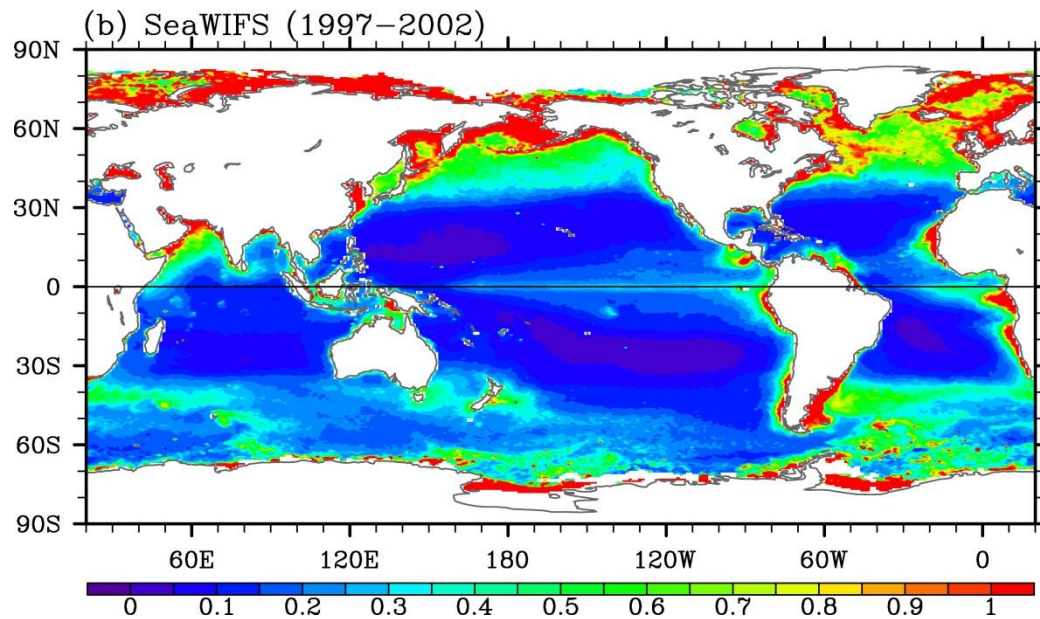
- ➔ Meridional resolution is 1° , whereas the zonal resolution varies between 1° in mid-latitudes and $1/3^\circ$ at the equator.
- ➔ 50 vertical layers with thicknesses ranging from 10 m over the top 200 m to a maximum thickness of 250 m at 5500m depth.
- ➔ Atmospheric forcing: Coordinated Ocean-ice Reference Experiment (CORE2).
- ➔ Initialized from the World Ocean Atlas with respect to temperature, salinity, nitrate, phosphate, and silicate.
- ➔ The simulation was spun-up for 300 years with forcing from the CORE2 atmospheric forcing during 1948-1977.
- ➔ The real-time simulation is run from 1948-2009.

MOM4-TOPAZ: Natural variability

Annual Mean Climatology: Chl (mg/m^3)

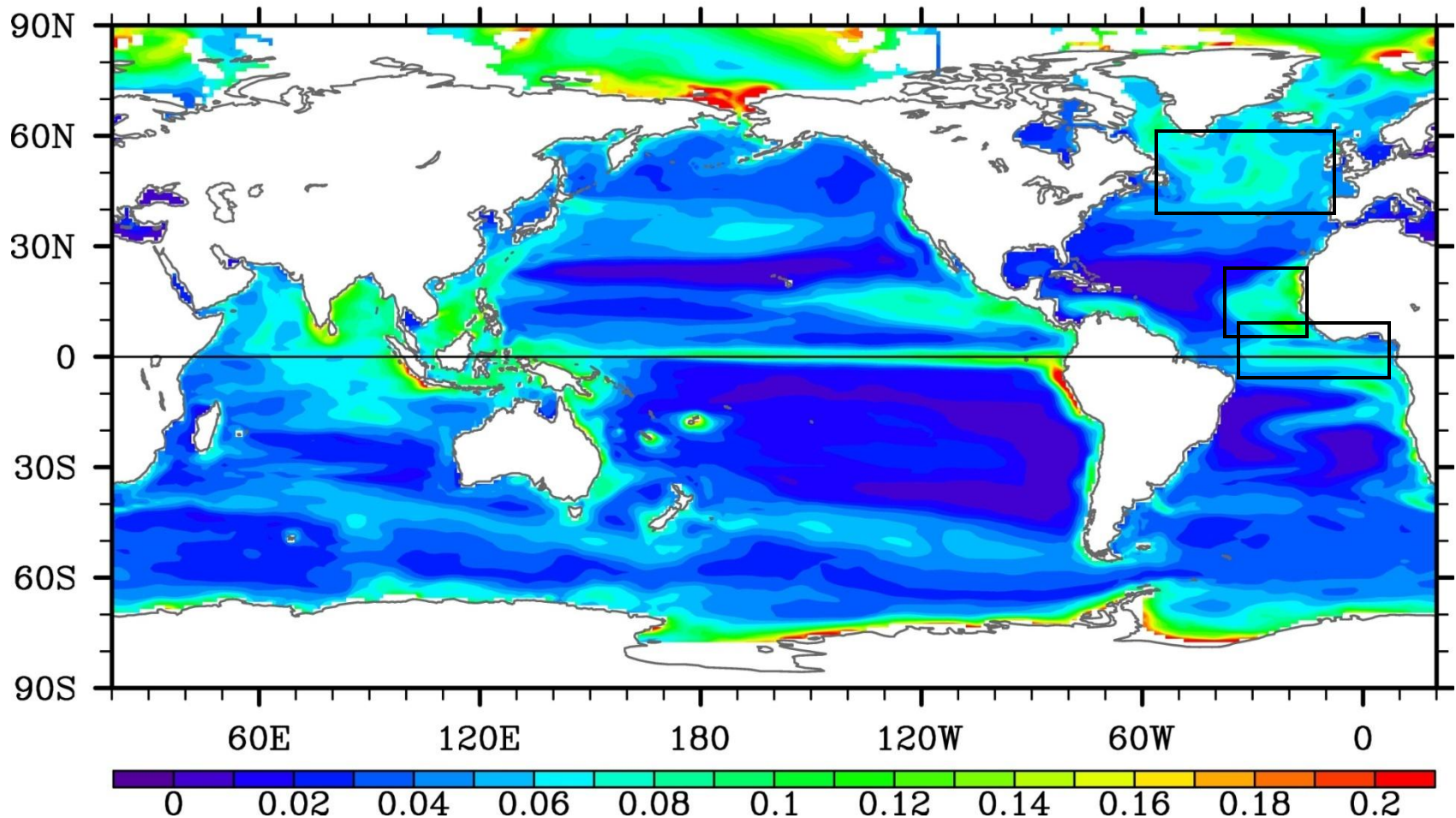


Surface chlorophyll is overall underestimated in MOM4-TOPAZ, but, its spatial pattern is reasonably realistic.



MOM4-TOPAZ: Natural variability

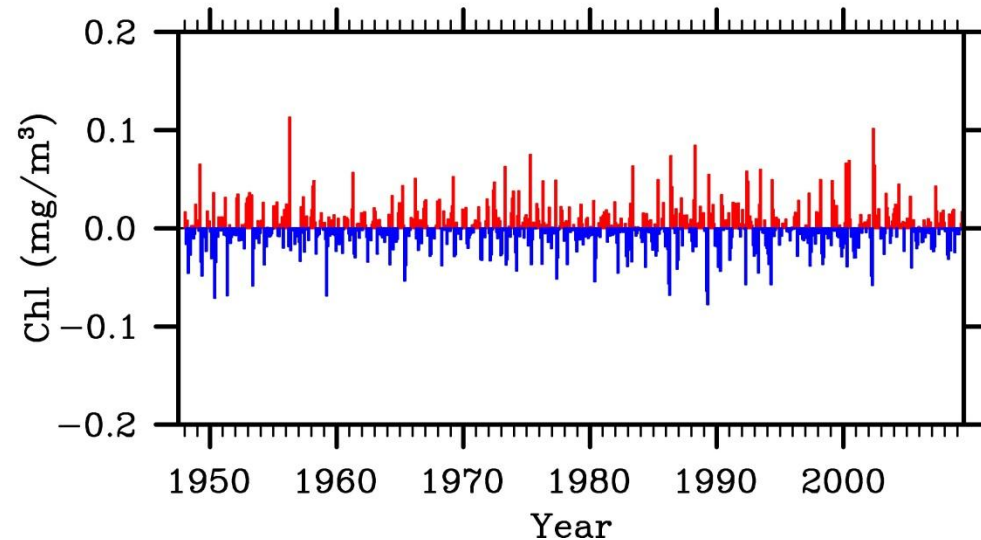
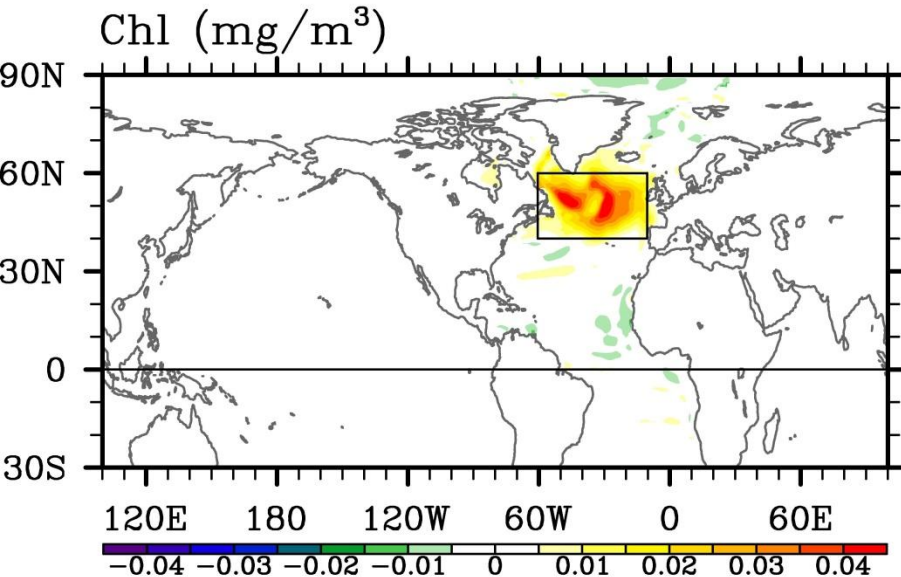
MOM4p1_TOPAZ: STD of Chl (mg/m^3)



High Chl variability in the subpolar NATL, northeastern tropical ATL, and equatorial ATL.

MOM4-TOPAZ: Natural variability

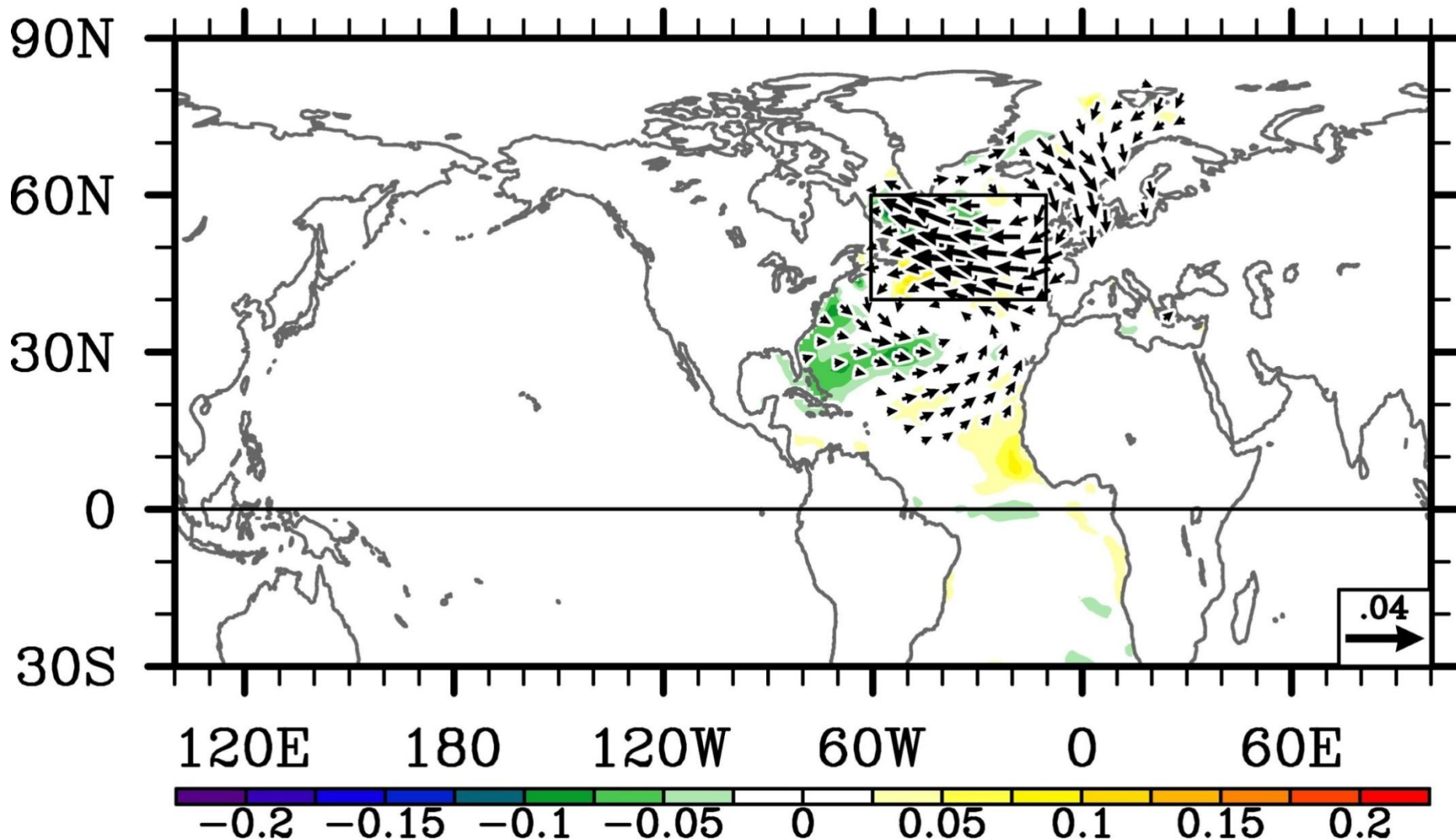
Subpolar North Atlantic



- Subpolar North Atlantic has high variability of Chl (STD/mean = 19%).
- But, there is no long-term variability.
- Subpolar North Atlantic Chl is significantly correlated with North Atlantic Oscillation ($r = -0.3$).
- Subpolar North Atlantic Chl variability is largely link to light

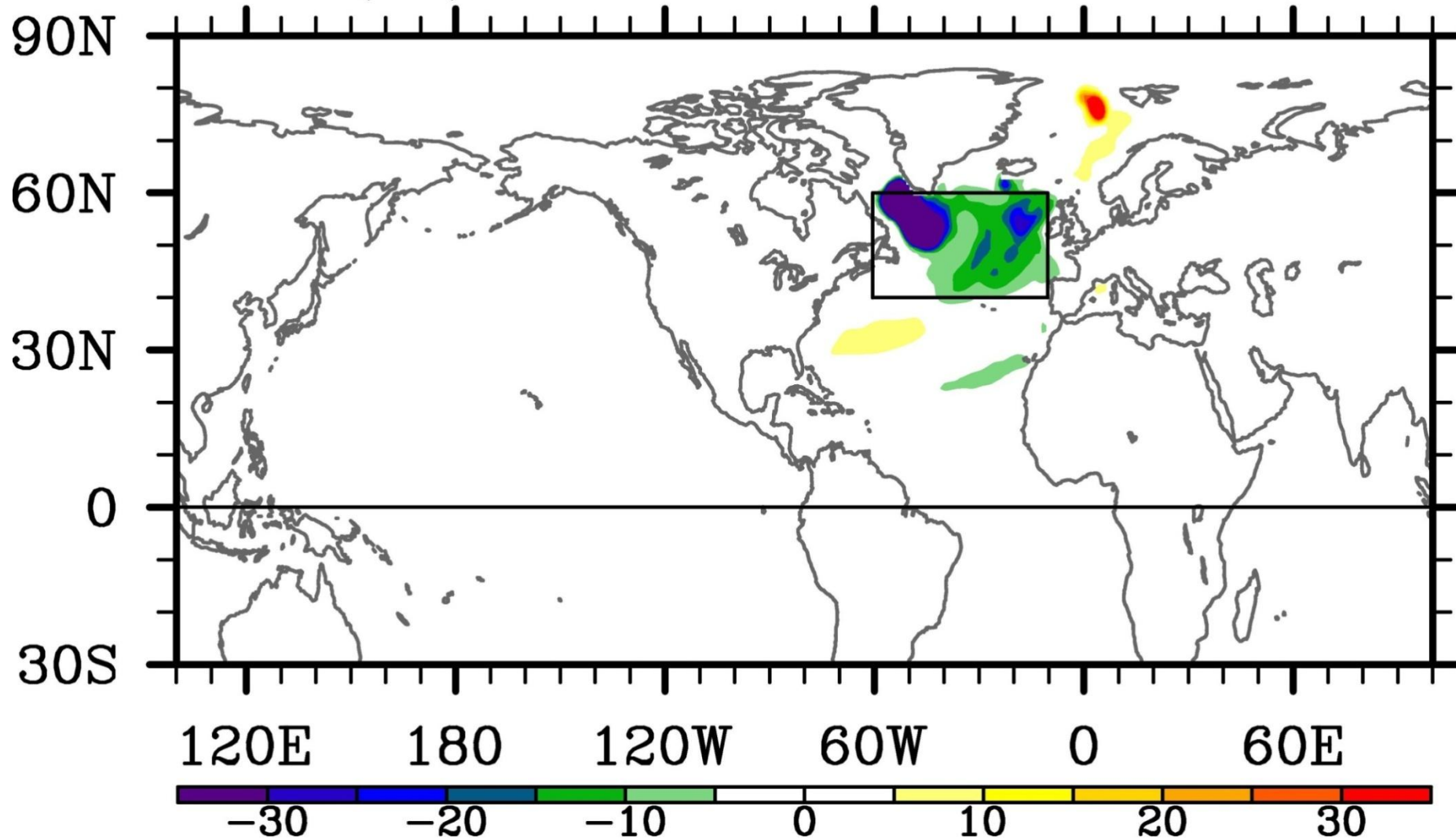
MOM4-TOPAZ: Natural variability

SST and Wind Stress



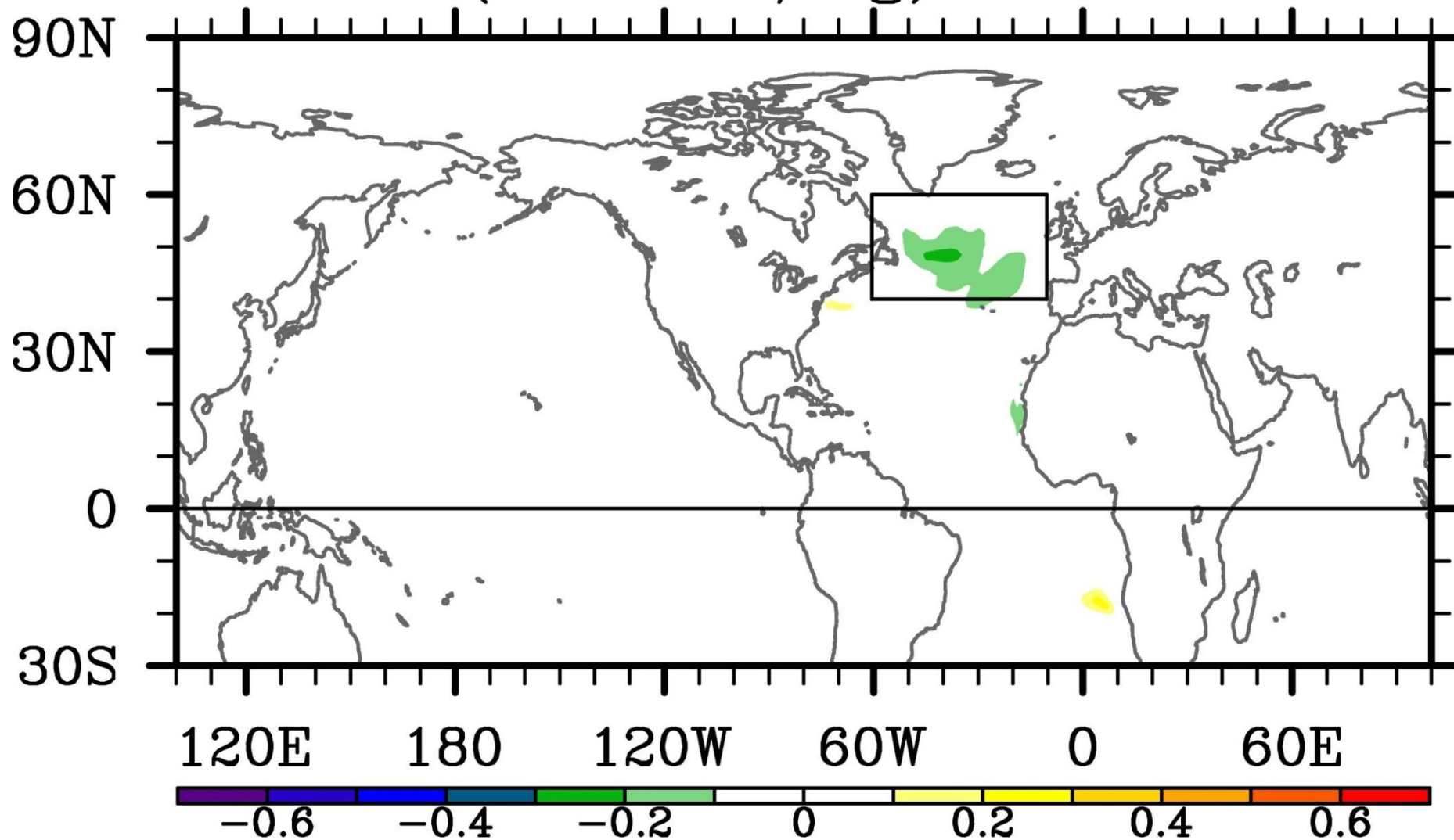
MOM4-TOPAZ: Natural variability

MLD (m)



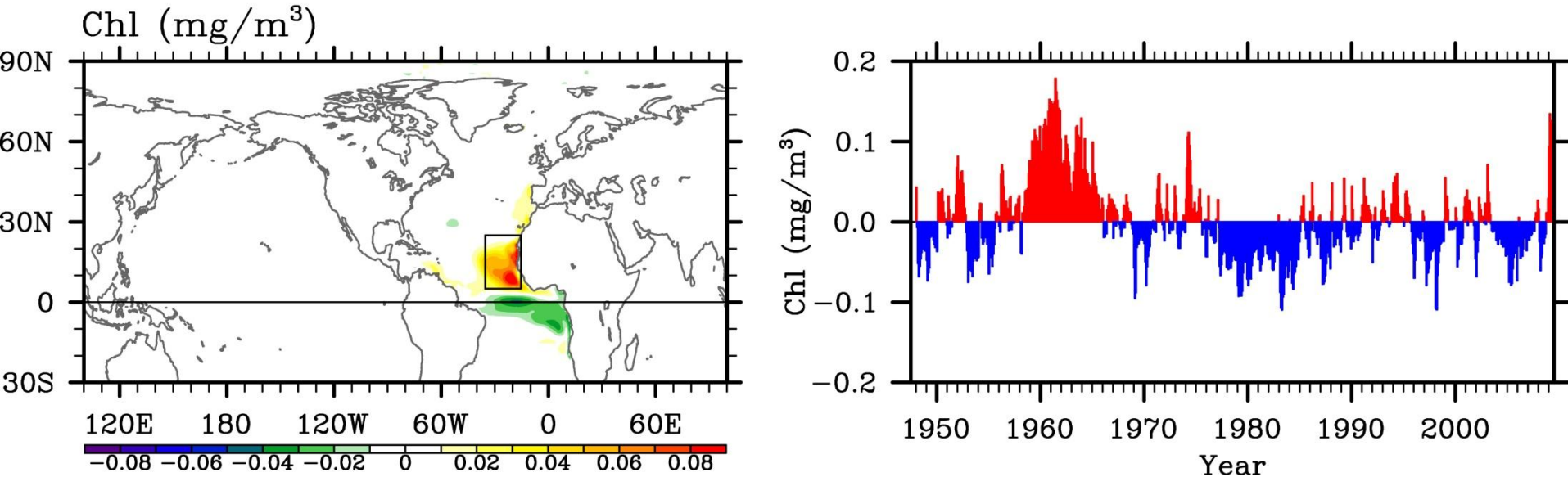
MOM4-TOPAZ: Natural variability

Nitrate (10^{-6}mol/kg)



MOM4-TOPAZ: Natural variability

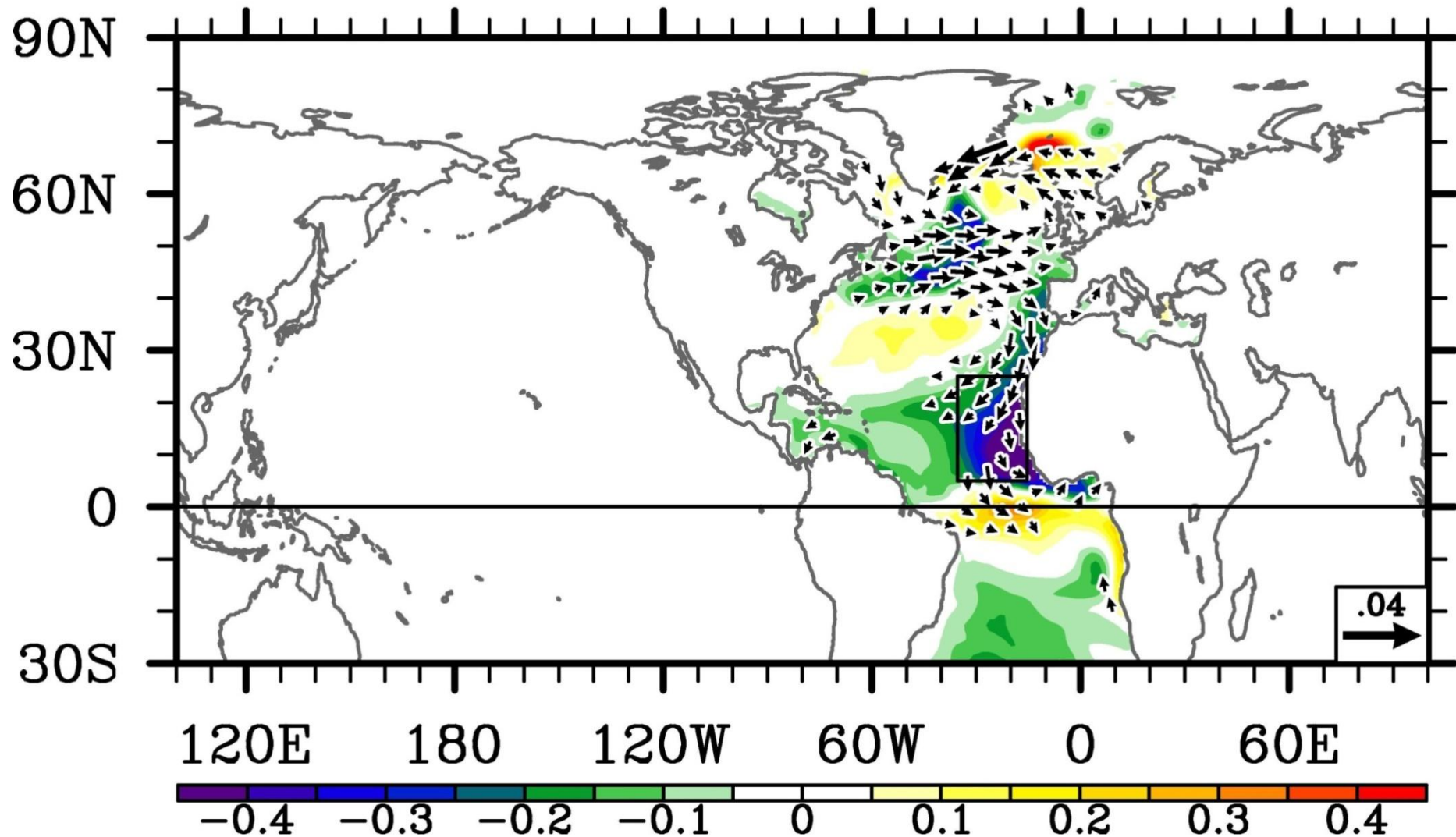
Northeastern Tropical Atlantic



- Dipole variability of Chl between northeastern tropical Atlantic and equatorial South Atlantic ($\text{STD}/\text{mean} = 34\%$).
- Chl in the northeastern tropical Atlantic decreased greatly during 1960s and 1970s. It is significantly anti-correlated with AMM and AMO.
- This region is one of the known habitats for Yellowfin Tuna (YFT)
- Beardsley (1969), and Mendessohn & Roy (1986) reported links between SSTs/upwelling and YFT catch.

MOM4-TOPAZ: Natural variability

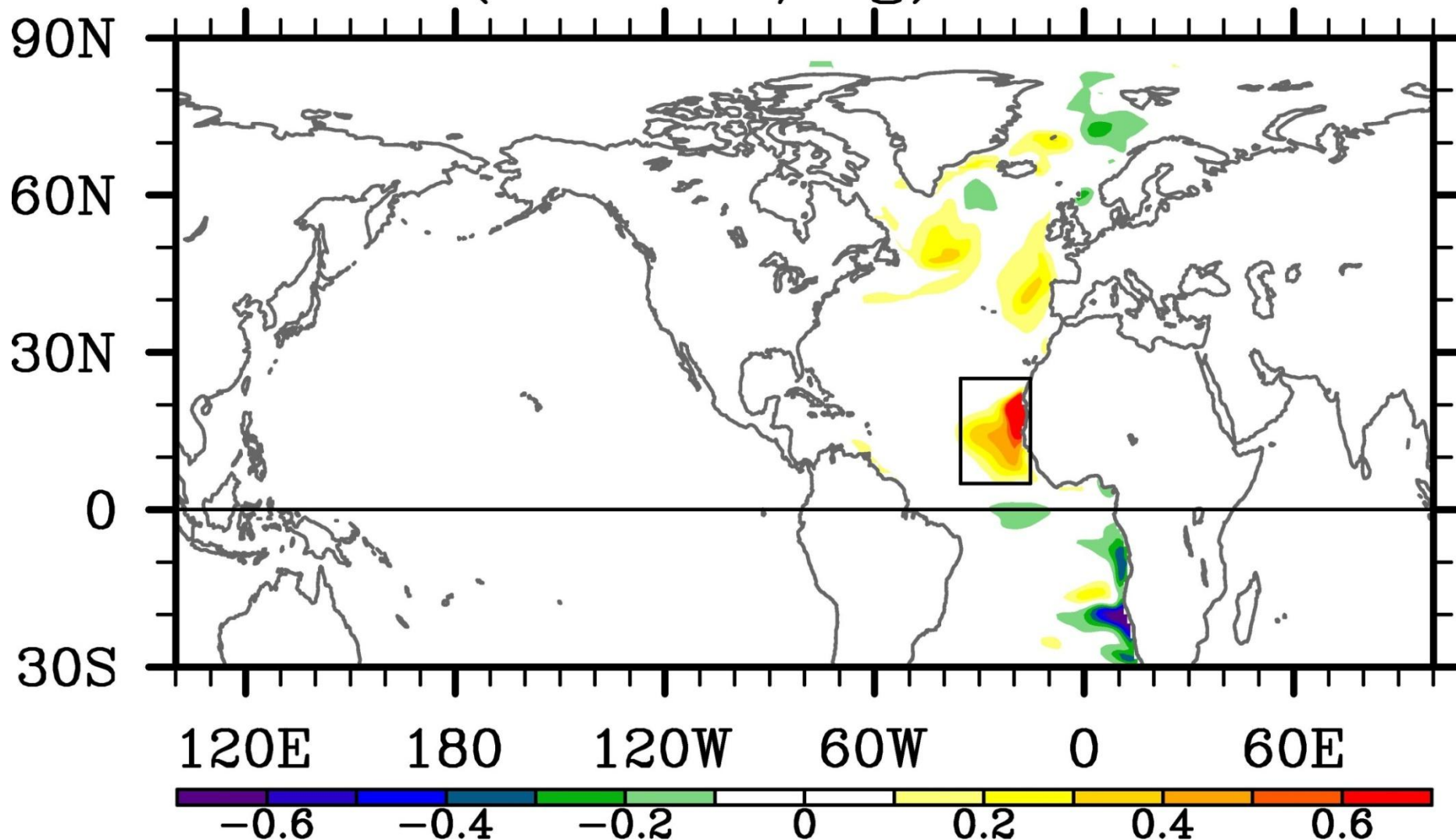
SST and Wind Stress



Increased trades ([-]AMM & [-]AMO) leads to increased upwelling of nutrients

MOM4-TOPAZ: Natural variability

Nitrate (10^{-6}mol/kg)

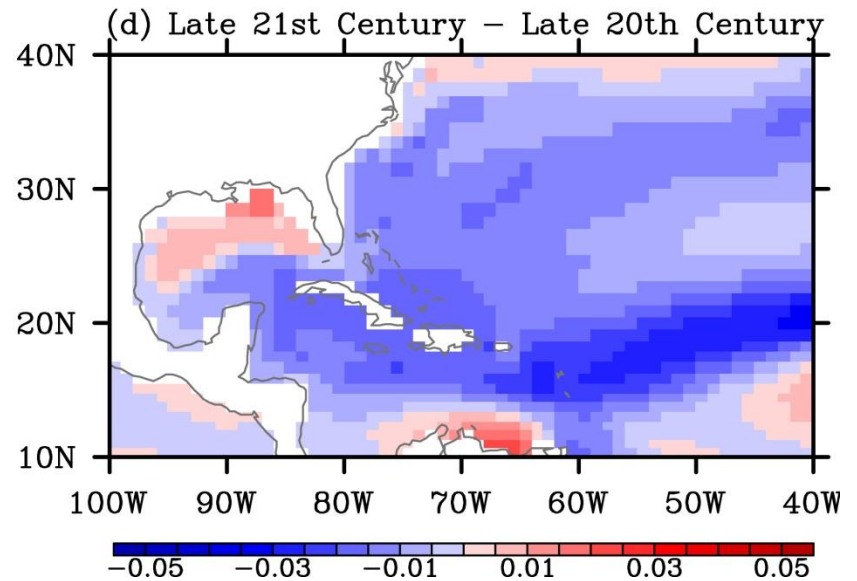
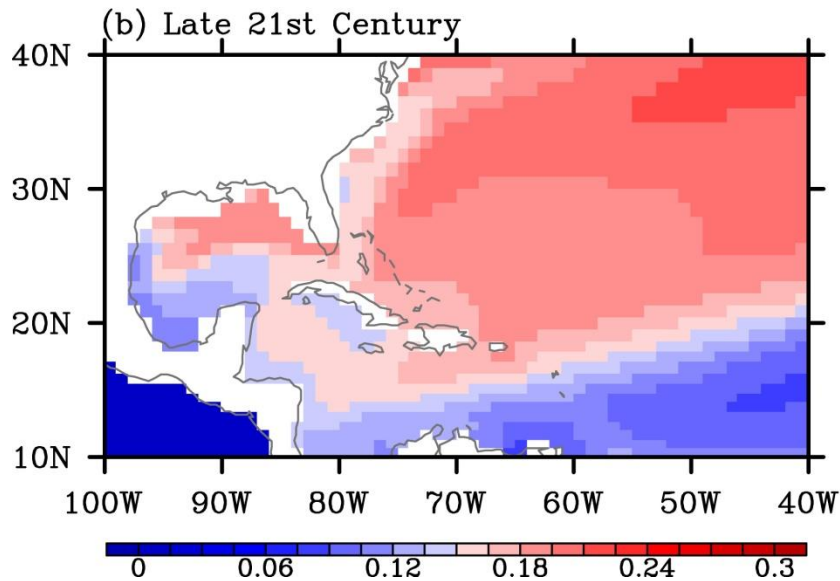
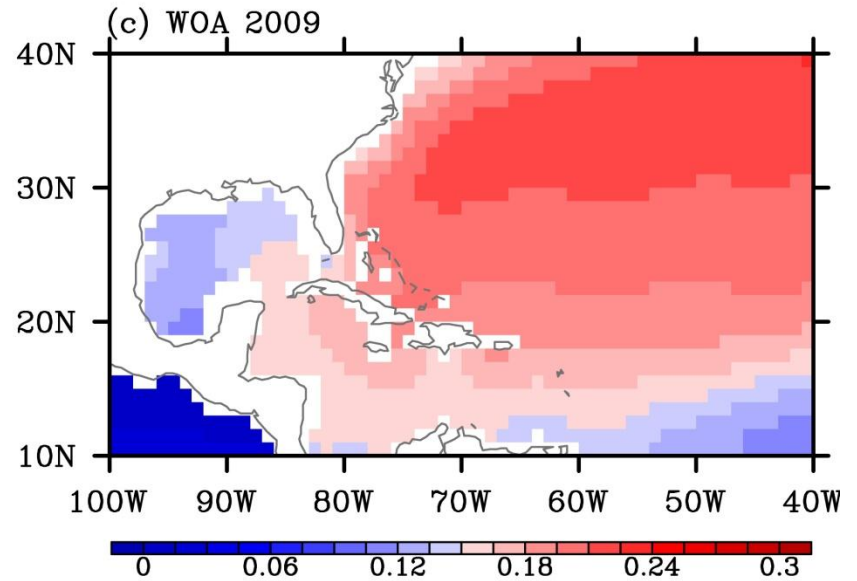
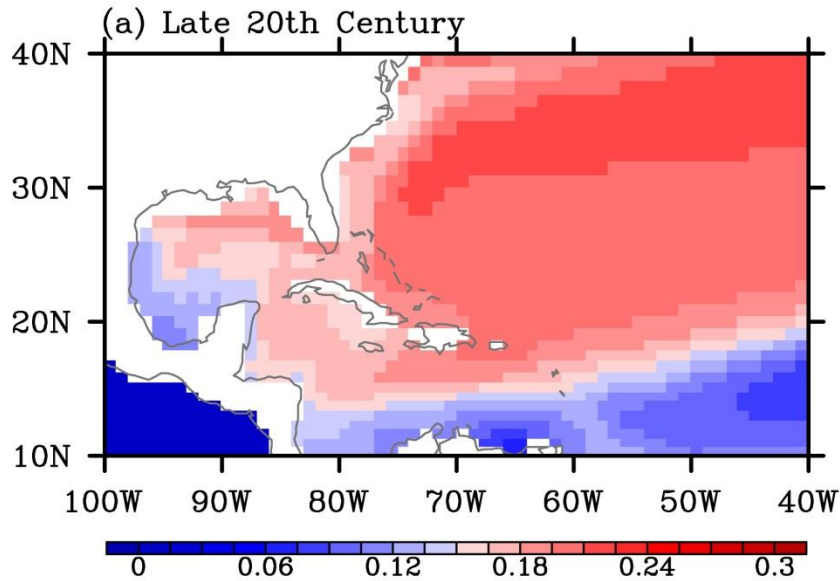


Natural variability of primary productivity in NATL

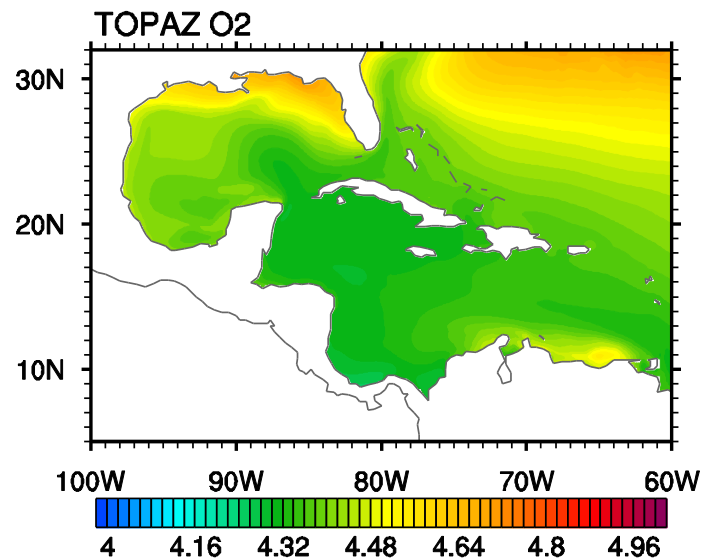
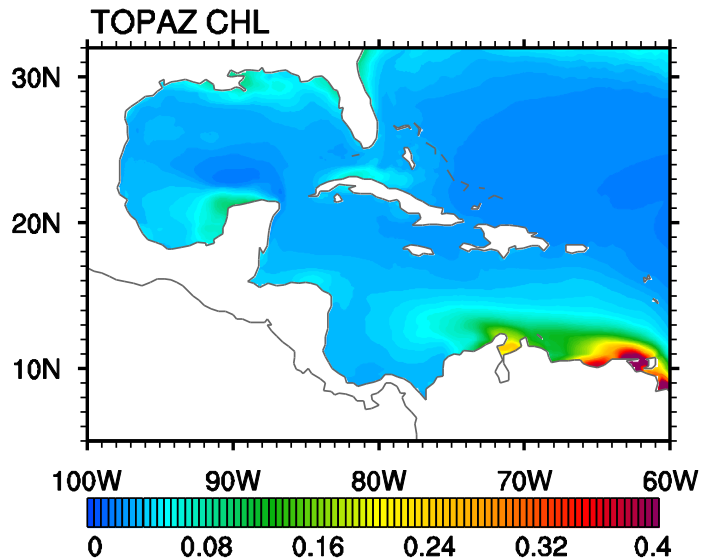
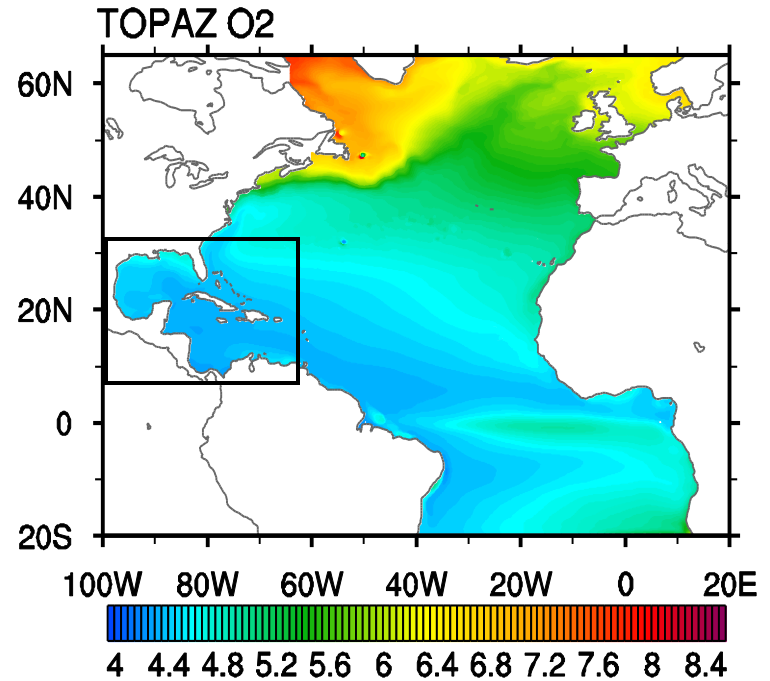
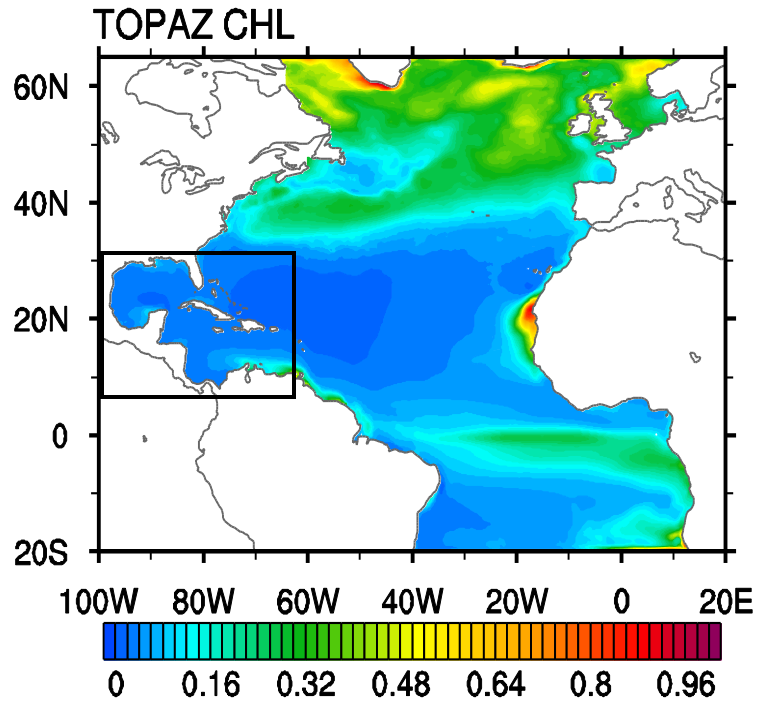
- High Chl variability in subpolar NATL, northeastern tropical ATL, and equatorial ATL.
- Subpolar NATL
 - ➔ Significantly correlated with NAO ($r = -0.3$), but not with AMO
 - ➔ Increased westerlies ([+] NAO) lead to deeper MLD and light limitation
- Northeastern tropical ATL
 - ➔ Significantly correlated with AMM ($r = -0.5$), and AMO ($r = -0.3$)
 - ➔ Increased trades ([-]AMM & [-]AMO) leads to increased upwelling of nutrients
- Equatorial ATL
 - ➔ Increased trades leads to increased upwelling of nutrients

CMIP5: Biogeochemical Modeling

GFDL_ESM2M & WOD09: DO (mol/m³) at 200m



Regional MOM4-TOPAZ (Surface)



Future Work

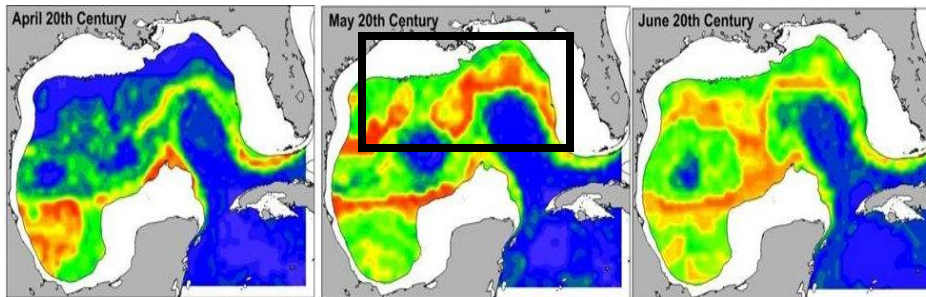
Downscale CMIP5 climate models using a regional ocean-biogeochemical model and study the impact of natural and anthropogenic climate variability on the GoM and apply results to the BFT habitat model.

April

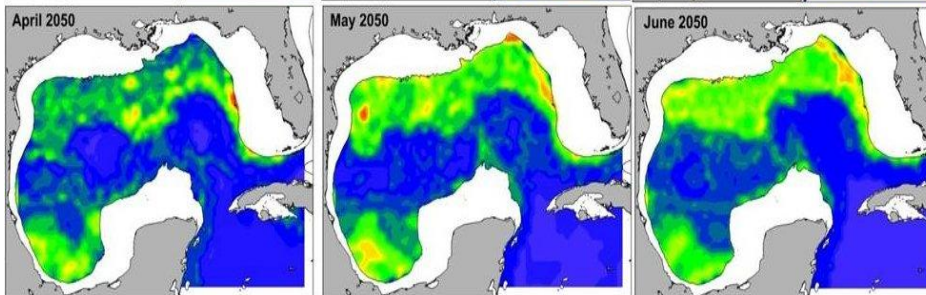
May

June

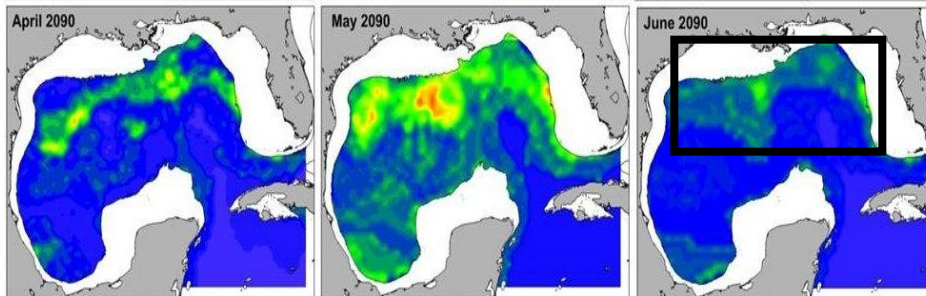
Late-20C



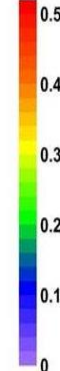
Mid-21C



Late-21C



Probability of larval occurrence (/1)



Due to projected warming, areas with high larval occurrence will decrease by more than 90% toward the end of the 21st century.

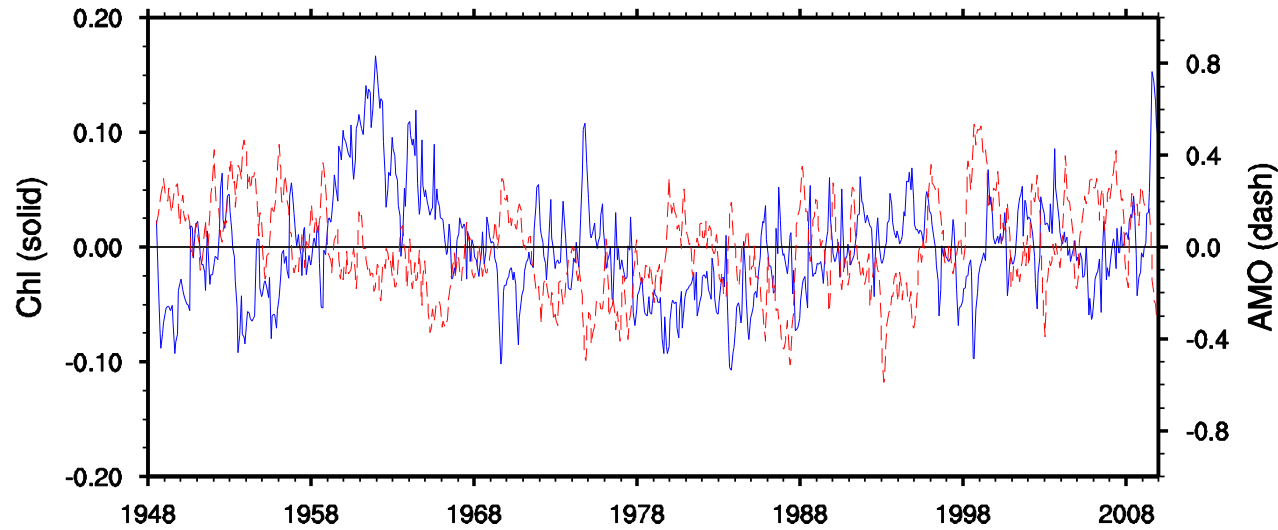
A large school of tuna swimming in clear blue water. The fish are sleek, silver, and have prominent dorsal fins. They are moving in a coordinated pattern, with some in the foreground and others receding into the background.

Thanks!

Comments and suggestions are welcome!

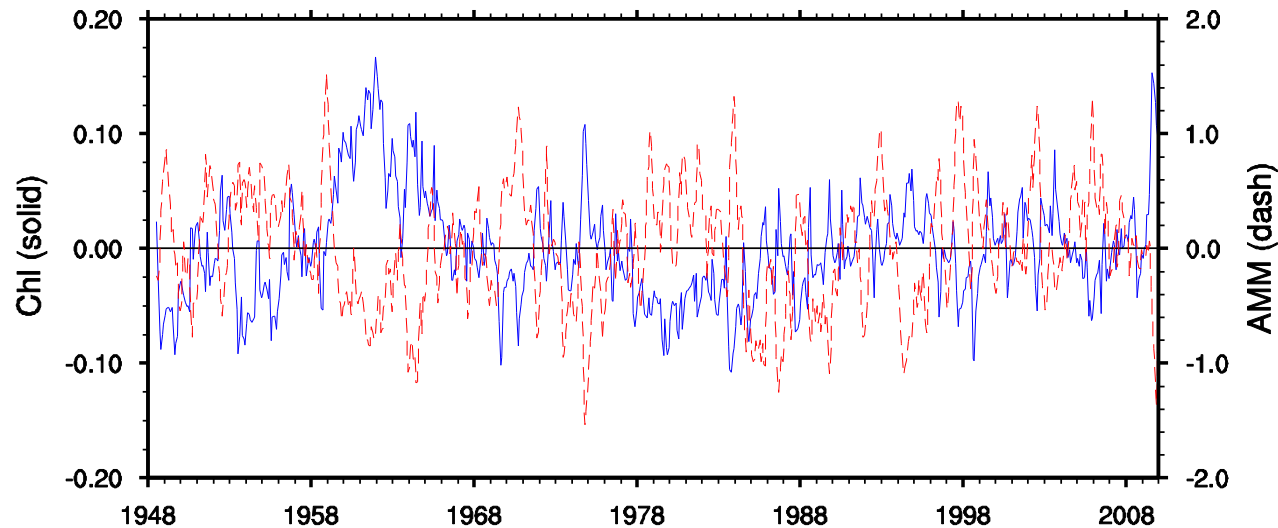
Chl in Northeastern tropical ATL

(a) Chl vs. AMO



Chl vs. AMO: -0.3

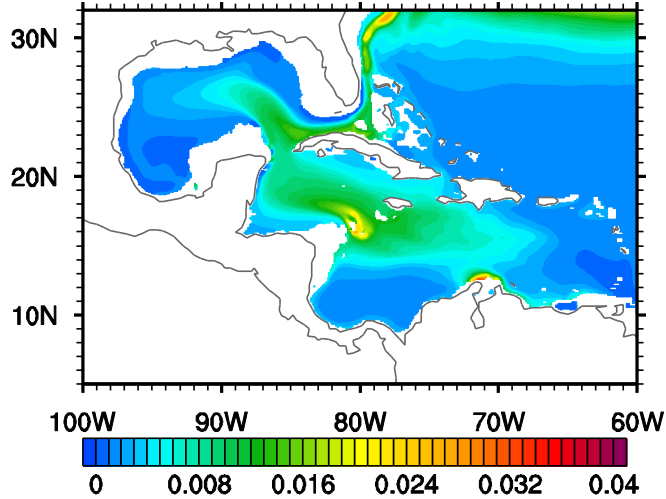
(b) Chl vs. AMM



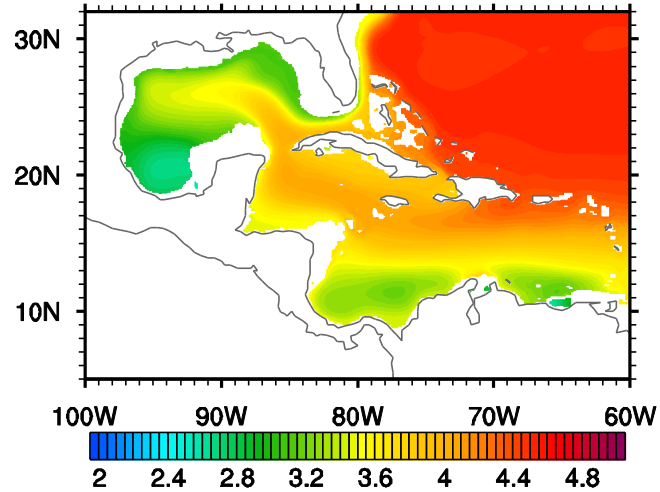
Chl vs. AMM: -0.5

Regional MOM4-TOPAZ (200m)

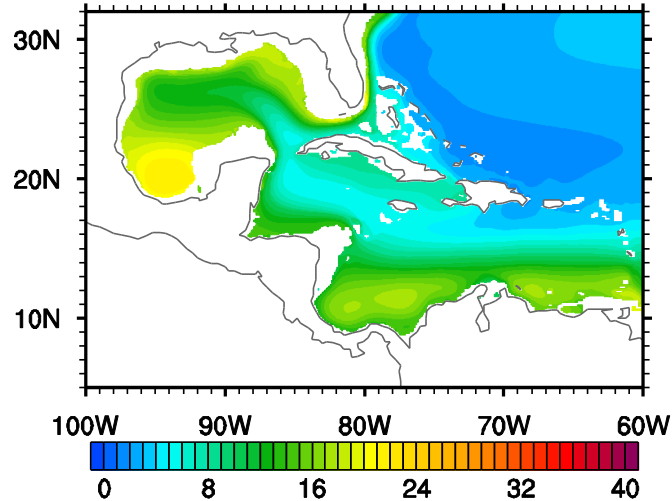
TOPAZ 200m CHL



TOPAZ 200m O2



TOPAZ 200m NO3



TOPAZ 200m PO4

